The effects of clove seed (*Syzygium aromaticum*) dietary administration on carcass characteristics, meat quality, and sensory attributes of broiler chickens

Gamaleldin M. Suliman,[*,†] Abdullah N. Alowaimer,[*] Saud I. Al-Mufarrej,[*] Elsayed O. S. Hussein,[*] Esam H. Fazea,[*] Mohammed A. E. Naiel,[‡] Rashed A. Alhotan,[*] and Ayman A. Swelum[*,§,1]

**Department of Animal Production, College of Food and Agriculture Sciences, King Saud University, 11451 Riyadh, Kingdom of Saudi Arabia; †Department of Meat Production, Faculty of Animal Production, University of Khartoum, Sudan; ‡Department of Animal Production, Faculty of Agriculture, Zagazig University, Zagazig 44511, Egypt; and §Department of Theriogenology, Faculty of Veterinary Medicine, Zagazig University, Zagazig 44511, Egypt*

ABSTRACT Previous studies have shown positive outcomes associated with the incorporation of cloves into broiler chicken diets. This study aimed to evaluate carcass characteristics, meat quality, and sensory attributes of broiler chickens fed diets supplemented with different clove seed levels. A total of 240 day-old Ross 308 broiler chicks were fed 1 of seven dietary treatments. The control group diet contained 0% clove seeds, whereas the treatment group diets contained up to 6% clove seeds. The chickens' final BW was significantly different between the treatments, which decreased linearly with increasing levels of clove seed inclusion. Broiler chickens fortified with clove seeds did not significantly affect the chickens' carcass characteristics and body composition. However, an increment in weights of carcass components (liver, heart, and gizzard) was observed in low clove seed levels. In addition, water-holding capacity, cooking loss percentages, and tenderness of the meat were improved owing to clove seed inclusion (1 or 2%) compared with the control group. Further studies are warranted to optimize the outstanding use of cloves toward broiler chicken performance enhancement and to produce a high quality of meat.

Key words: clove seed, broiler, meat quality, carcass

2021 Poultry Science 100:100904
https://doi.org/10.1016/j.psj.2020.12.009

INTRODUCTION

Since 2006 until now, there is a rising demand for elimination of the antibiotics used as growth promoters in poultry production because of its residuals in the final meat products (Muaz et al., 2018; Hussein et al., 2020) and the development of antibiotic-resistant bacteria strains in consumers (El-Shall et al., 2020). The wide-ranging consumer refusal of synthetic additives has been rising in current times (Kirkpinar et al., 2014). For these aforementioned reasons, supplementation of poultry rations with natural components to enhance production is extensively assumed in the world (Abou-Elkhair et al., 2020). Consequently, the herb spices and their bioactive constituents have gained importance in poultry production because of their valuable impacts on the growth, production, immune status, and meat quality without leaving residues in the product or the rearing environment (El-Hack and Alagawany, 2015; El-Hack et al., 2015; Abd El-Hack et al., 2016; Hussein et al., 2019). Cloves (*Syzygium aromaticum*) are aromatic flower buds from an evergreen tree belonging to the Myrtaceae plant family (Mbaveng and Kuete, 2017). They are considered medicinal plants in addition to nutritional spices in China and Eastern countries against several bacterial diseases (Wankhede, 2015). This 8- to 12-m plant grows in tropical climates such as Indonesia, India, the West Indies, Brazil, Sri Lanka, Tanzania, and Madagascar (Bhowmik et al., 2012).

Clove buds contain approximately 15 to 20% volatile essential oils dominated by eugenol (70–85%) (Pino et al., 2001; Lutterodt et al., 2010; Ramadan et al., 2013; El-Maati et al., 2016). Clove, and its essential oil, is one of the plant extracts found useful in poultry to improve growth performance by enhancing the intestinal microbiota population (Mohammadi

Received October 5, 2020.
Accepted December 2, 2020.
[1]Corresponding author: aswelum@ksu.edu.sa

et al., 2014). Thus, several studies had been demonstrated to evaluate the effect of broiler chicken diets supplemented with cloves on performance, carcass, and production traits of broilers. Mohammadi et al. (2014) found that broiler chicken diets fortified with 100 and 300 mg/kg of clove oil enhanced the performance and feed conversion ratio via increased gastrointestinal villus height and crypt depth. In addition, Agostini et al. (2012) investigated using several quantities of clove oil as a dietary supplement for broiler chickens, citing improvements in feed efficiency and growth performance for all experimental groups of chickens. In another study, Salman and Ibrahim (2012) reported that feed diets supplemented with 0.8% clove powder and a 0.8% clove flower oil combination and drinking water treated with 0.4% aqueous clove extract improved the performance of broiler chickens exposed to heat stress. Similar results by Mukhtar (2011) indicated that chicken feed diet supplemented with several clove oil concentrations (200, 400, and 600 mg/kg diet) promotes live BW, feed intake, feed conversion ratio, and carcass yield, as well as reduces mortality rates. Besides, significant improvements in live BW gain, total feed intake, and feed conversion ratio and decreased total cholesterol levels were observed in the chicken group fed 450 mg/kg clove oil compared with other treated groups (Azadegan et al., 2014). In addition, a diet supplemented with 400 mg/kg clove extract could be useful as a natural growth promoter for poultry instead of antibiotics and enhance the performance parameters (Boyraz and Özcan, 2006).

Dietary spices containing essential oils can also be responsible for improving digestion (Lee et al., 2004). Several studies have stated the encouraging effect of spices or their bioactive compounds on the digestibility process (Murugesan et al., 2015; Mustafa, 2016; Mandey et al., 2019). They have been revealed to promote bile salt hydrolase enzymes and other digestive enzyme secretion from the intestinal mucosa and pancreas (Jang et al., 2007). It is hypothesized that improvement in nutrients digestibility, intestinal microbiota population, and the intestinal mucosa structure are involved in the clove's mode of action. However, little is known about the dietary clove seeds in poultry-produced meat. Thus, our work aimed to gain more information about the effect of clove seed administration within broiler diets on carcass traits, quality, and sensory attributes of produced meat.

MATERIAL AND METHODS

Chickens, Feed, and Management

This study approved and followed the rearing chickens' ethical instruments and sampling collection of the live animals' ethical guidelines by the Research Ethics Committee, College of Food and Agricultural Sciences, King Saud University, Saudi Arabia (NO: KSU-SE-20-35).

This study used 420 day-old commercial Ross 308 broiler chicks. The chicks were feather-unsexed, individually weighed, and randomly allocated equally into 7 groups, each assigned to an experimental treatment. Each treated group had 10 replicates involving 6 birds per each (60 chicks per group). The chickens were housed in electrically heated battery cages. Lighting was incandescent and continuous throughout the experimental period, by following Schwean-Lardner and Classen (2010) lighting program instructions.

The experimental chickens were fed a starter diet (23% protein and 3,000 ME kcal/kg) until 21 d of age. At 21 d, the chickens were fed 1 of seven dietary treatments, as shown in Table 1. The diets containing 6 levels of cloves were isonitrogenous and isocaloric. The control group contained 0% clove seeds, while the rest of the treatments contained 1, 2, 3, 4, 5, and 6% clove seeds, respectively. Feed and water were provided ad libitum. The chicken weights and feed intake were measured every wk during the experimental period.

Slaughter and Carcass Measurements

By following the study by Shafey et al. (2014), on day 39 of the experiment, 3 birds were randomly selected per pen for carcass and meat quality characteristic measurements as previously described by Chen et al. (2013). The jugular vein was cut using a sharp knife to guarantee maximum and rapid blood loss for humane slaughtering after 10 h of feed and water deprivation. Then, the feathers, heads, shanks, viscera, and abdominal fat were removed, and the remaining carcasses were dissected.

Data collected from carcass weight, abdominal fat, and cut parts (breast and leg) were recorded. The maximum safe level of clove seed for maximum carcass weight was estimated to be 1.61% ± 0.28 ($R^2 = 0.99$). The dressing percentage was calculated as a result of dividing hot carcass weight over final live weight. The left breast from each chicken was retained for later meat quality analyses.

Meat Quality Parameters

Initial and final pH values were recorded 20 min and 24 h postmortem (**P.M.**) using a pH meter (Model pH 211; Hanna Instruments, Woonsocket, Rhode Island). The initial internal breast muscle temperature was measured 20 min P.M. using a portable thermocouple (EcoScan Series, Temp JKT; Eutech Instruments, Singapore, Singapore). The color coordinates of the CIE-LAB Color System, L^* (lightness), a^* (redness), and b^* (yellowness) were determined on breast muscles 20 min and 24 h P.M. using a CR-400 Chroma Meter (Konica Minolta, Tokyo, Japan). The breasts were then frozen at −80°C for future analyses. The frozen muscles were thawed overnight in a fridge at 4°C before the examination. The water-holding capacity (**WHC**) was measured as per the technique outlined by Wilhelm et al. (2010). Cooking loss (**CL**) was determined as the difference between the initial and final weights, expressed as a

Table 1. Treatments, ingredient proportions and chemical composition.

		Treatment group (clove seeds level)						
Ingredients (%)	Starter	C (0%)	T_1 (1%)	T_2 (2%)	T_3 (3%)	T_4 (4%)	T_5 (5%)	T_6 (6%)
Corn	57.25	58.60	57.36	56.11	54.87	53.62	52.38	51.48
Soybean meal	30.00	30.80	31.12	31.44	31.76	32.08	32.40	32.00
Wheat bran	0	2.50	2	1.50	1	0.50	0	0
Corn gluten meal	6	0	0	0	0	0	0	0
Clove seeds	0	0	1	2	3	4	5	6
Choline chloride	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Palm oil	2.19	4.40	4.82	5.24	5.66	6.08	6.50	6.80
Dicalcium phosphate	2.30	1.93	1.94	1.96	1.97	1.98	1.99	1.99
Limestone	0.70	0.57	0.57	0.56	0.56	0.55	0.55	0.55
Salt	0.40	0.21	0.21	0.21	0.21	0.21	0.21	0.21
VM Mix[1]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
DL-Methionine	0.18	0.17	0.17	0.17	0.17	0.18	0.18	0.18
Lysine-HCL	0.32	0.14	0.13	0.13	0.12	0.12	0.11	0.11
Threonine	0.11	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total	100	100	100	100	100	100	100	100
Chemical composition								
ME (kcal/kg)	3,000	3,100	3,100	3,100	3,100	3,100	3,100	3,100
CP (%)	23	20	20	20	20	20	20	20
Methionine (%)[2]	0.51	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Lysine (%)[2]	1.28	1.13	1.13	1.13	1.13	1.13	1.13	1.13
Sulfur amino acids (%)[2]	0.95	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Threonine (%)[2]	0.86	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Calcium (%)	0.96	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Phosphorus (%)	0.47	0.41	0.41	0.41	0.41	0.41	0.41	0.41

[1]Vitamin-mineral premix contains in the following per kg: choline chloride, 70%; betain HCL, 98%; diclazuril, 1%; Kemzyme; vitamin A, 20000000 IU; vitamin D3, 6000000 IU; vitamin E, 60,000 mg; vitamin K3, 4,000 mg; vitamin B1, 4,000 mg; vitamin B2, 12,000 mg; vitamin B6, 8,000 mg; vitamin B12, 20,000 mg; nicotinamide, 80,000 mg; biotine, 200,000 mg; folic acid, 2,000 mg; Ca d-pantothenate, 20,000 mg; manganese, 150,000 mg; zinc, 120,000 mg; iron, 96,000 mg; copper, 20,000 mg; Iodine, 2,000 mg; selenium, 400 mg.

[2]Amino acids were presented in a digestible form.

percentage of the initial weight. The cooked samples were also used to evaluate shear forces as per the procedure described by Wheeler et al. (2001). After the samples were cooled to room temperature (21°C), 3-round cores (1.27 cm in diameter) were removed from each muscle sample parallel to the muscle fibers' longitudinal orientation using a manual coring device. Shear force was determined as the maximum force (kg) perpendicular to the fibers using a TA.HD Texture Analyzer (Stable Micro Systems, Surrey, UK) fitted with a Warner-Bratzler attachment. The crosshead speed was set at 200 mm/min.

The texture profile analysis variables were determined after breast muscle samples being cooked by following Wilhelm et al. (2010) procedure. Then, subsamples were obtained by scoring the muscles parallel to the longitudinal direction of the muscle fibers with a handheld corer's aid. The texture profile analysis was conducted using the TA.HD Texture Analyzer (Stable Micro Systems) equipped with a compression-plate attachment. Each sample underwent 2 cycles of 80% compression. The variables determined were as follows: hardness, which is the maximum force needed to compress the sample; cohesiveness, which is a ratio between the total energy required for the first and second compression; springiness, which represents the ability of a sample to recover to its original form after removal of the compressing force; and chewiness, which is defined as the product of springiness x hardness x cohesiveness.

The myofibril fragmentation index (**MFI**) of the breast muscle was determined as described by Al-Owaimer et al. (2014). A 4-g muscle sample was scissor-minced, then homogenized (Ultra Turrax; IKA-Werke, Staufen, Germany) with 40 mL of cold isolating MFI buffer. The absorbance of a 0.5 mg/mL solution was determined at 540 nm using HACH DR/3000 Spectrophotometer, and then, MFI was determined by multiplying the absorbance value by the dilution factor.

As per juiciness, tenderness, flavor intensity, and overall acceptability on an 8-point category scale, the meat samples used for sensory evaluation tests were grouped based on the category scaling method. The frozen samples were thawed overnight at 4°C, then wrapped in an aluminum foil, and cooked in an oven at 200°C to an internal temperature of 70°C. After that, the cooked samples were cut into small pieces of approximately 2 cm^3 and assigned a random code number for identification. The samples were presented warm on numbered plates for evaluation. Ten semitrained panelists were requested to rate each meat sample (10 samples per day). The mean of all panel assessments was determined to define the sample characteristic. The panelists were devoid to food and smoking 2 h before the test. Water and crackers were available to remove any residual flavor of the previous samples. Any sort of communication between the panelists during the sensory evaluation sessions was denied.

Statistical Analysis

The obtained results were statistically analyzed by applying 1-way ANOVA using SPSS software (IBM

SPSS Ver. 22; IMB Corp., Armonk). Data were tested for normality before ANOVA analysis using the Kolmogorov-Smirnov test (Massey Jr, 1951). All percentage data were arcsine-transformed before analysis. The significant differences between means were tested using Tukey's range test at a CI of 95% ($P < 0.05$). The maximum safe level of clove seed was calculated using the Broken-Line (descending Linear) Model according to Alhotan et al. (2017). The obtained data were expressed as mean ± SEM.

RESULTS

Carcass and Body Components

The carcass and body components of broiler chickens affected by the diets supplemented with different quantities of clove seeds are shown in Table 2. The chickens' final BW were significantly ($P < 0.05$) varied between the treated groups. The control group (0% clove seeds) obtained the highest final live weights, while the 6% clove seed group obtained the lowest final live weights. The last live weights of the chickens decreased linearly as the levels of clove seed inclusion increased. Although the 1 and 2% clove seed groups had lower final live weights than the control group, the differences between them were not significant.

Carcass weights were also significantly ($P < 0.05$) different between the treatment groups, following the same trend as the final live weights, where the control and 6% clove seed groups attained the highest and lowest weights, respectively. Once again, the 1 and 2% clove seed groups showed lower carcass weight values than the control group, and the differences between them were not significant. The dressing percentages differed significantly ($P < 0.05$) between the treatment groups. The control group achieved the highest dressing value, whereas the 5% clove seed group achieved the lowest value.

The treatment groups differed significantly ($P < 0.05$) in all body components except the leg. The most substantial breast weights were observed in the control group, while the smallest breast weights were found in the 6% clove seeds group. The breast weights showed the same pattern as the final live weights, carcass weights, and dressing percentages; the breast weights decreased as the clove seeds' levels increased. In contrast, the liver, gizzard, and heart showed the opposite pattern concerning clove supplementation. These factors increased in weight with increasing levels of clove seeds. The abdominal fat values showed a gradual significant ($P < 0.05$) decrease with increasing clove seed inclusion but an insignificant increase compared with the control group.

Physical Meat Properties

The physical meat properties of broiler chickens fed different levels of clove seeds are presented in Table 3. The initial temperature taken 20 min P.M. differed significantly ($P < 0.05$) between the treatment groups. The control group (0%) showed the highest (27.25°C) initial temperature, whereas the (3%) treatment group reflected the lowest value.

The initial and final pH values were significantly ($P < 0.05$) different between the treatment groups. The control group showed the highest initial and final pH values. Generally, the pH value is taken 24 h P.M. which decreased with increasing clove seed inclusion levels, up to 5% clove seeds. The 1% clove seed group showed the lowest value (6.25) of initial pH, while the all treated group with clove seed showed the lowest value (6.03) of final pH. Lightness (L^*) values increased with increasing clove seed inclusion, up to 3% clove seeds at 1 h P.M.; the L^* values 24 h.

According to our study result, postmortem generally decreased with increasing clove seed levels. The redness (a^*) value was significantly ($P < 0.05$) different between the treatment groups at 1 h P.M. but not so at 24 h P.M. At 1 h P.M., the 6% group showed the highest value (7.47) of a*, whereas the 1% group showed the lowest value (5.32). This result indicated that redness (a^*) values were increased as the level of clove seeds increased. At 24 h P.M., the (6%) treatment group also attained the highest ($P > 0.05$) value (6.87) of a* color coordinate, while the (3%) group attained the lowest value (5.64). Yellowness (b*) color coordinate was significantly ($P < 0.05$) different between the treatment groups at both 1 and 24 h P.M. The control group

Table 2. Carcass and body components of broiler chickens fed different levels of clove seeds.

Parameter	Clove seed level 0%	1%	2%	3%	4%	5%	6%	SEM	P Value Linear	Quadratic
Final live weight (kg)	2.42^{a}	2.34^{a}	2.36^{a}	2.17^{b}	1.87^{c}	1.69^{d}	1.49^{e}	1.49	0.023	0.001
Carcass weight (kg)	1.61^{a}	1.52^{a}	1.52^{a}	1.35^{b}	1.17^{c}	1.02^{d}	0.91^{d}	1.20	0.045	0.012
Dressing (%)	66.54^{a}	64.73^{a}	64.68^{a}	62.28^{b}	62.50^{b}	60.59^{b}	60.68^{b}	0.37	0.015	0.031
[1]Body components										
Leg (%)	29.03	30.24	29.74	29.85	30.72	30.90	30.94	0.23	0.857	0.458
Breast (%)	41.98^{a}	40.43^{a,b}	41.28^{a}	40.51^{a,b}	38.89^{b,c}	38.71^{b,c}	37.99^{c}	0.31	0.035	0.002
Liver (%)	3.01^{b}	3.10^{b}	3.23^{b}	3.63^{a,b}	3.41^{a,b}	3.95^{a}	3.90^{a}	0.08	0.024	0.895
Gizzard (%)	3.79^{c}	3.74^{c}	4.01^{b,c}	4.13^{b,c}	4.29^{b,c}	4.65^{a,b}	5.19^{a}	0.11	0.015	0.634
Heart (%)	0.63^{c}	0.67^{b,c}	0.68^{b,c}	0.73^{b,c}	0.71^{b,c}	0.80^{a,b}	0.87^{a}	0.02	0.023	0.524
Abdominal fat %	1.53^{a,b}	2.03^{a}	1.52^{a,b}	1.66^{a,b}	1.61^{a,b}	1.57^{a,b}	1.11^{b}	0.10	0.031	0.045

$^{a–e}$Mean values of different superscripts on the same row are significantly different at ($P < 0.05$, 0.01, or 0.001).
[1]Body components were computed as a ratio to the carcass weight.

Table 3. Meat physical properties of broiler chickens fed different levels of clove seeds.

Parameter	Clove seed level 0%	1%	2%	3%	4%	5%	6%	SEM	*P* Value Linear	Quadratic
Temperature (°C)	27.25[a]	26.41[a,b,c]	26.15[b,c]	23.23[d]	26.95[a,b]	26.16[b,c]	25.95[c]	0.20	0.018	0.003
$pH_{initial}$	6.43[a]	6.25[b]	6.30[a,b]	6.31[a,b]	6.31[a,b]	6.36[a,b]	6.31[a,b]	0.02	0.010	0.241
pH_{final}	6.26[a]	6.06[b]	6.04[b]	6.03[b]	6.03[b]	6.03[b]	6.08[b]	0.01	0.041	0.022
Color values at 1 h *postmortem*										
*L**	36.39	35.19	36.47	37.27	34.90	35.18	34.02	0.45	0.052	0.368
*a**	5.99[b]	5.32[b]	5.79[b]	6.24[b]	5.96[b]	5.98[b]	7.47[a]	0.15	0.044	0.152
*b**	5.37[a]	4.82[a,b]	5.07[a]	4.46[a,b]	3.96[b]	4.33[a,b]	4.63[a,b]	0.13	0.013	0.295
Color values at 24 h *postmortem*										
*L**	37.53[a]	36.06[a,b]	38.22[a]	34.42[b]	35.93[a,b]	36.45[a,b]	33.82[b]	0.40	0.025	0.020
*a**	6.38	5.71	6.25	5.64	5.87	5.81	6.87	0.15	0.754	0.315
*b**	6.91[a]	6.64[a,b]	6.67[a,b]	5.38[c]	5.51[b,c]	6.10[a,b,c]	6.03[a,b,c]	0.16	0.037	0.054

[a–e]Mean values of different superscripts on the same row are significantly different at ($P < 0.05$, 0.01, or 0.001).

(0%) showed the highest value of b* at both 1 h P.M. (5.37) and 24 h P.M. (6.91). On the other side, the (4%) treatment group showed the lowest values of b* at 1 h P.M. (3.96), whereas the (3%) group showed the lowest value (5.38) at 24 h P.M.

Meat Quality Characteristics

Table 4 reveals the results of meat quality characteristics of broiler chickens fed different levels of clove seeds. The treatment groups were significantly ($P < 0.05$) different in all meat parameters except MFI and cohesiveness. Generally, WHC, CL, and MFI decreased with increasing clove seed inclusion. The most favorable values for WHC, CL, and MFI were obtained by 3, 6, and 0% treatment groups, respectively. The 3% group achieved the best WHC ratio (0.29) compared with the other treatment groups followed by 0 and 2 > 4 > 6 > 5 > 1%. The most convenient CL value (22.47%) was obtained by the 6% group. Contrary, the worst value (31.75%) of CL was obtained by group 0% (control).

The least shear force (1.21 kg), which indicates most tenderness, was reported by the 6% clove seed group, followed by the control group (1.39 kg). The highest value of shear force (1.77 kg), which is an indication of tough meat, was showed by the 5% treatment group. The 4 and 5% clove seed groups showed the lowest values for hardness (0.72) and chewiness (2.10), respectively, while the 2% clove seeds group showed the highest values (1.67 and 4.96) for these parameters, respectively.

Sensory Indices Evaluation

Subjective evaluation of the samples from the different treatment groups did not indicate significant differences in meat qualities (juiciness, flavor intensity, overall acceptability) except for tenderness (Table 5). All sensory evaluation attributes were not significantly different between the treatment groups except tenderness. The highest rating scores 4.58, 5.60, and 5.42 of juiciness, tenderness, and flavor intensity, respectively, were for the 1% group. In comparison, the highest (5.85) overall acceptability rating score was for the 4% group, which was immediately followed by the 1% group that obtained 5.83. The difference between groups 4 and 1% was not significantly different.

DISCUSSION

The expansion of antibiotic-resistant pathogenic bacterium has always been the side effect of its use in the poultry diet of subtherapeutic antibiotic concentration (Hussein et al., 2020). In addition, consumers are worried about using antibiotics in animal diets, including residue contamination of final poultry products and development of antibiotic-resistant pathogens (Agyare et al., 2018). Unlike traditional

Table 4. Meat quality characteristics of broiler chickens fed different levels of clove seeds.

Parameter	Clove seed level 0%	1%	2%	3%	4%	5%	6%	SEM	*P* Value Linear	Quadratic
WHC	0.25[a,b]	0.21[b]	0.25[a,b]	0.29[a]	0.24[a,b]	0.22[b]	0.23[a,b]	0.01	0.032	0.012
Cooking loss%	31.75[a]	26.73[b,c]	28.93[a,b]	27.56[b,c]	27.24[b,c]	23.47[c,d]	22.47[d]	0.62	0.012	0.001
MFI	77.68	75.92	74.35	77.54	72.76	70.25	73.99	0.96	0.821	0.049
Shear force (kg)	1.39[a,b]	1.54[a,b]	1.72[a]	1.40[a,b]	1.72[a]	1.77[a]	1.21[b]	0.06	0.034	0.005
Texture profile analysis										
Hardness (kg)	1.00[b]	1.15[b]	1.67[a]	0.96[b]	0.72[b]	0.76[b]	1.12[b]	0.06	0.018	0.001
Springiness	0.55[c]	0.59[b,c]	0.61[a,b]	0.59[b,c]	0.64[a]	0.58[b,c]	0.56[c]	0.01	0.024	0.013
Cohesiveness	0.49	0.49	0.50	0.49	0.48	0.48	0.50	0.01	0.058	0.062
Chewiness	2.70[b]	3.33[b]	4.96[a]	2.76[b]	2.19[b]	2.10[b]	3.03[b]	0.19	0.022	0.028

[a–e]Mean values of different superscripts on the same row are significantly different at ($P < 0.05$, 0.01 or 0.001).
Abbreviations: MFI, myofibril fragmentation index; WHC, water-holding capacity.

Table 5. Sensory evaluation of broiler chickens fed different levels of clove seeds.

	Clove seed level								*P* Value	
Parameter	0%	1%	2%	3%	4%	5%	6%	SEM	Linear	Quadratic
Juiciness	4.42	4.58	3.90	4.10	4.35	4.44	4.10	0.11	0.047	0.102
Tenderness	$4.96^{a,b}$	5.60^{a}	4.50^{b}	$4.67^{a,b}$	$5.13^{a,b}$	$5.06^{a,b}$	$4.67^{a,b}$	0.13	0.025	0.116
Flavor intensity	4.98	5.42	4.67	4.83	5.06	5.27	4.73	0.11	0.345	0.057
Overall acceptability	5.21	5.83	5.02	5.31	5.85	5.81	4.85	0.14	0.965	0.121

[a–e]Mean values of different superscripts on the same row are significantly different at ($P < 0.05$, 0.01, or 0.001).
Meat samples were rated from 1 to 8, with 8 points being the most desirable level.

production, antibiotic usage is not permissible in organic systems. Thus, organic and conventional poultry production requires alternative strategies to enhance poultry growth and performance (Diaz-Sanchez et al., 2015). Herbs, spices, and various other natural plant compounds are being assessed as effective alternatives to antibiotics and approximately do have promoting growth effects, antibacterial properties, and other health-related advantages (Ionescu, 2017; Al-Sagheer et al., 2019; Abou-Elkhair et al., 2020; Naiel et al., 2020).

The results obtained in this study concurred with those obtained by Mohammadi et al. (2014), reporting lower growth performance of broiler chickens fed high levels of clove. In contrast, Ertas et al. (2005) revealed that supplementing a broiler diet with a 200 mg/kg mixture of oregano, clove, and anise oils enhanced the daily weight gain. Moreover, Mukhtar (2011) found that clove oil (600 mg/kg) improved broilers' final BW compared with the control and antibiotic-treated groups. The study of Azadegan et al. (2014) confirmed that BW gain was significantly enhanced in broilers that received 450 mg/kg clove oil from 23 to 42 d of age. Kaur et al. (2019) found that clove buds contain the highest values from saponin and the lowest oxalate value. Concerning biological role, saponin has been defined as an antinutritional agent in most cases (Chaudhary et al., 2018). In some cases, it has been maintained to decrease feed intake, inhibit growth rate in poultry, and show some toxicologic effects with higher levels in diets (Miah et al., 2004).

In our study result, the dressing percentage decreased with increasing quantities of clove seeds supplemented in the diet. Inline, Azadegan et al. (2014) did not observe any significant improvement in carcass traits for broilers fed with the diet supplemented with clove oil. Contrary to this finding, Tariq et al. (2015) cited an increase in dressing percentage and breast weight of chickens fed clove. This discrepancy could be ascribed to the high level of clove seed inclusion applied in our study. In addition, Abd El-Hack et al. (2015) mentioned that carcass traits were better than those of the control group in Japanese quails fed with the clove oil–enriched diet. The variation may be owing to the difference in the supplementation form of clove. This investigation was in line with Dalkiliç and Güler (2009) study that feed diets fortified up to 0.04% clove extract could be applied as an effective growth promoter for broilers alternative to antibiotics.

The results of abdominal fat obtained in this study agreed with that of Dalkiliç and Güler (2009) who reported a significant ($P < 0.05$) reduction in abdominal fat content in cooperation with the high level of clove extract within the broiler diet. In contrast, Chowdhury et al. (2018) concluded that clove oil administration in poultry diets did not affect carcass characteristics. Researchers stated that saponins from different plant resources had decreased meat and serum cholesterol level in broiler chickens (Matsuura, 2001; Afrose et al., 2010; Gaurav, 2015; Chaudhary, 2017). In addition, the interaction between saponin and bile acids in the gastrointestinal tract encourages the development of large mixed micelles, enhancing high cholesterol excretion (Oakenfull, 1986) and finally decreasing serum, organ, and meat cholesterol levels.

Although there were significant differences between the treatment groups in initial carcass temperature, this result could be attributed to the carcass preparation method rather than the treatment. The traditional scalding and defeathering process used in this study involves dipping chickens into a boiling tank with temperatures between different batches. The gap between them relied mainly on how fast the processing steps (Macagnan et al., 2012).

Although the shear force and texture profile analysis results showed inconsistent patterns concerning the supplemented clove seeds, the higher inclusion of clove seeds in groups 6 and 4% resulted in the best value of shear force and hardness, respectively. It was also true for springiness and cohesiveness. The sensory evaluation results showed an overall improvement in palatability as a consequence of clove seed inclusion. It could be ascribed to the antioxidant properties of clove seeds that inhibited lipid oxidation of meat, which is known to be the main reason behind meat quality spoiling resulting in rancidity and formation of unacceptable odors and flavors (Amaral et al., 2018). Generally, there was an improvement in meat tenderness expressed in response to clove seed inclusion. Thus, meat quality could be improved by adding natural antioxidants, and clove has the highest antioxidant capacity related to its high phenolic content (Velasco and Williams, 2011). However, some studies have reported that natural antioxidants have no impact on the sensory attributes of meat. For example, Hernández et al. (2010), Shan et al. (2005), and Wheeler et al. (2001) concluded that supplementation with clove essential oil did not alter any adverse effect on chicken meat quality.

CONCLUSION

From the obtained results, we concluded that broiler diets fortified with a small amount of clove seed (up to 1.91% ± 0.20) could significantly promote the final BW, quality, physical and sensory attributes traits of meat, and some carcass characteristics. Conversely, the high level of clove seed supplemented within broiler diets up to 6% significantly increased internal organ weight (liver, gizzard, and heart). Hence, broiler chicken diets supplemented with clove seeds could be a safe alternative to antibiotics as growth promoters and produce harmless meat with numerous beneficial effects on consumer health.

ACKNOWLEDGMENTS

The authors thank the Deanship of Scientific Research and RSSU at King Saud University for their technical support.

Funding: The authors extend their appreciation to the deputyship for Research & Innovation, "Ministry of Education" in Saudi Arabia for funding this research work through the project number IFKSUHI-139.

DISCLOSURES

The authors declare no conflicts of interest.

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.psj.2020.12.009.

REFERENCES

Abd El-Hack, M. E., and M. Alagawany. 2015. Performance, egg quality, blood profile, immune function, and antioxidant enzyme activities in laying hens fed diets with thyme powder. J. Ani. Feed Sci. 24:127–133.

Abd El-Hack, M. E., M. Alagawany, M. Ragab Farag, R. Tiwari, K. Karthik, K. Dhama, J. Zorriehzahra, and M. Adel. 2016. Beneficial impacts of thymol essential oil on health and production of animals, fish and poultry: a review. J. Essent. Oil Res. 28:365–382.

Abd El-Hack, M. E., S. A. Mahgoub, M. Alagawany, and K. Dhama. 2015. Influences of dietary supplementation of antimicrobial cold pressed oils mixture on growth performance and intestinal microflora of growing Japanese quails. Int. J. Pharm. 11:689–696.

Abou-Elkhair, R., H. Abdo Basha, W. Slouma Hamouda Abd El Naby, J. S. Ajarem, S. N. Maodaa, A. A. Allam, and M. A. E. Naiel. 2020. Effect of a diet supplemented with the Moringa oleifera seed powder on the performance, egg quality, and Gene expression in Japanese laying quail under heat-stress. Animals 10:809.

Afrose, S., M. Hossain, and H. Tsujii. 2010. Effect of dietary karaya saponin on serum and egg yolk cholesterol in laying hens. Br. Poult. Sci. 51:797–804.

Agostini, P., D. Sola-Oriol, M. Nofrarías, A. Barroeta, J. Gasa, and E. Manzanilla. 2012. Role of in-feed clove supplementation on growth performance, intestinal microbiology, and morphology in broiler chicken. Livestock Sci. 147:113–118.

Agyare, C., V. E. Boamah, C. N. Zumbi, and F. B. Osei. 2018. Antibiotic use in poultry production and its effect on bacterial resistance. In: Kumar Y., ed, Antimicrobial Resistance—A Global Threat, IntechOpen; London, UK.

Alhotan, R. A., D. V. Vedenov, and G. M. Pesti. 2017. Estimation of the maximum safe level of feed ingredients by spline or broken-line nonlinear regression models. Poult. Sci. 96:904–913.

Al-Owaimer, A. N., G. M. Suliman, A. H. Alyemni, and A. M. Abudabos. 2014. Effect of different probiotics on breast quality characteristics of broilers under *Salmonella* challenge. Ital. J. Ani. Sci. 13:3189.

Al-Sagheer, A. A., M. E. Abd El-Hack, M. Alagawany, M. A. E. Naiel, S. A. Mahgoub, M. M. Badr, E. O. Hussein, A. N. Alowaimer, and A. A. Swelum. 2019. Paulownia leaves as a new feed resource: chemical composition and effects on growth, carcasses, digestibility, blood biochemistry, and intestinal bacterial populations of growing rabbits. Animals 9:95.

Amaral, A. B., M. V. d. Silva, and S. C. D. S. Lannes. 2018. Lipid oxidation in meat: mechanisms and protective factors–a review. Food Sci. Technol. 38:1–15.

Azadegan, M. M., A. Hassanabadi, M. H. Nasiri, and H. Kermanshahi. 2014. Supplementation of clove essential oils and probiotic to the broiler's diet on performance, carcass traits and blood components. Res. Opin. Ani. Vet. Sci. 4:218–223.

Bhowmik, D., K. S. Kumar, A. Yadav, S. Srivastava, S. Paswan, and A. S. Dutta. 2012. Recent trends in Indian traditional herbs *Syzygium aromaticum* and its health benefits. J. Pharm. Phytochem. 1:13–23.

Boyraz, N., and M. Özcan. 2006. Inhibition of phytopathogenic fungi by essential oil, hydrosol, ground material and extract of summer savory (*Satureja hortensis* L.) growing wild in Turkey. Int. J. Food Microbiol. 107:238–242.

Chaudhary, S. 2017. Assessment of the Performance of Broiler Breeders Fed Diet Containing Soapnut (Sapindus Mukorossi) Shell Powder, PhD Thesis. Indian Veterinary Research Institute (IVRI), Izatnagar, Uttar Pradesh, India.

Chaudhary, S. K., J. J. Rokade, G. N. Aderao, A. Singh, M. Gopi, A. Mishra, and K. Raje. 2018. Saponin in poultry and monogastric animals: a review. Int. J. Curr. Microbiol. Appl. Sci. 7:3218–3225.

Chen, X., W. Jiang, H. Tan, G. Xu, X. Zhang, S. Wei, and X. Wang. 2013. Effects of outdoor access on growth performance, carcass composition, and meat characteristics of broiler chickens. Poult. Sci. 92:435–443.

Chowdhury, S., G. P. Mandal, and A. K. Patra. 2018. Different essential oils in diets of chickens: 1. Growth performance, nutrient utilisation, nitrogen excretion, carcass traits and chemical composition of meat. Ani. Feed Sci. Technol. 236:86–97.

Dalkiliç, B., and T. Güler. 2009. The effects of clove extract supplementation on performance and digestibility of nutrients in broilers. FU Sag Bil Vet. Derg 23:161–168.

Diaz-Sanchez, S., D. D'Souza, D. Biswas, and I. Hanning. 2015. Botanical alternatives to antibiotics for use in organic poultry production. Poult. Sci. 94:1419–1430.

El-Maati, M. F. A., S. A. Mahgoub, S. M. Labib, A. M. Al-Gaby, and M. F. Ramadan. 2016. Phenolic extracts of clove (*Syzygium aromaticum*) with novel antioxidant and antibacterial activities. Eur. J. Integr. Med. 8:494–504.

El-Shall, N. A., A. M. Awad, M. E. A. Abd El-Hack, M. A. E. Naiel, S. I. Othman, A. A. Allam, and M. E. Sedeik. 2020. The Simultaneous administration of a probiotic or Prebiotic with live Salmonella Vaccine improves growth performance and Reduces Fecal Shedding of the bacterium in *Salmonella*-Challenged broilers. Animals 10:70.

Ertas, O. N., T. Guler, M. Çiftçi, B. DalkIlIç, and U. G. Simsek. 2005. The effect of an essential oil mix derived from oregano, clove and anise on broiler performance. Int. J. Poult. Sci. 4:879–884.

Gaurav, A. K. 2015. Page 78 in Studies on Supplementation of Chlorophytum Root and Camellia Seed as Feed Additives in Broiler Ration, PhD Thesis. Indian Veterinary Research Institute (IVRI), Izatnagar, Uttar Pradesh, India.

Hernández, P., V. Juste, C. Zomeño, J. Moreno, and P. Peñalver. 2010. Effect of dietary clove essential oil on poultry meat quality. Accessed Jul. 2020. http://icomst-proceedings.helsinki.fi/papers/2009_01_70.pdf.

Hussein, M. M., M. E. Abd El-Hack, S. A. Mahgoub, I. M. Saadeldin, and A. A. Swelum. 2019. Effects of clove

(*Syzygium aromaticum*) oil on quail growth, carcass traits, blood components, meat quality, and intestinal microbiota. Poult. Sci. 98:319–329.

Hussein, E. O., S. H. Ahmed, A. M. Abudabos, M. R. Aljumaah, M. M. Alkhlulaifi, M. A. Nassan, G. M. Suliman, M. A. E. Naiel, and A. A. Swelum. 2020. Effect of antibiotic, Phytobiotic and probiotic supplementation on growth, blood Indices and intestine health in broiler chicks Challenged with *Clostridium perfringens*. Animals 10:507.

Ionescu, M. I. 2017. Are herbal products an alternative to antibiotics?. in: S. Kırmusaoğlu, ed., Bacterial Pathogenesis and Antibacterial Control, Sahra, IntechOpen; London, UK.

Jang, I., Y. Ko, S. Kang, and C. Lee. 2007. Effect of a commercial essential oil on growth performance, digestive enzyme activity and intestinal microflora population in broiler chickens. Ani. Feed Sci. Technol. 134:304–315.

Kaur, K., S. Kaushal, and R. Rani. 2019. Chemical composition, antioxidant and Antifungal Potential of clove (*Syzygium aromaticum*) essential oil, its Major compound and its Derivatives. J. Essent. Oil Bearing Plants 22:1195–1217.

Kirkpinar, F., H. Ünlü, M. Serdaroğlu, and G. Turp. 2014. Effects of dietary oregano and garlic essential oils on carcass characteristics, meat composition, colour, pH and sensory quality of broiler meat. Br. Poult. Sci. 55:157–166.

Lee, K.-W., H. Everts, and A. C. Beynen. 2004. Essential oils in broiler nutrition. Int. J. Poult. Sci. 3:738–752.

Lutterodt, H., M. Luther, M. Slavin, J.-J. Yin, J. Parry, J.-M. Gao, and L. L. Yu. 2010. Fatty acid profile, thymoquinone content, oxidative stability, and antioxidant properties of cold-pressed black cumin seed oils. Lwt-food Sci. Technol. 43:1409–1413.

Macagnan, J., M. P. Pattussi, R. Canuto, R. L. Henn, A. G. Fassa, and M. T. A. Olinto. 2012. Impact of nightshift work on overweight and abdominal obesity among workers of a poultry processing plant in southern Brazil. Chronobiol. Int. 29:336–343.

Mandey, J. S., F. R. Wolayan, C. J. Pontoh, and B. Sondakh. 2019. Phytochemical characterization of cucumber (*Cucumis sativus* L.) seeds as candidate of water additive for organic broiler chickens. J. Adv. Agric. Technol. 6:61–64.

Massey, Jr, F.J. 1951. The Kolmogorov-Smirnov test for goodness of fit. J. Am. Statistical Assoc. 46:68–78.

Matsuura, H. 2001. Saponins in garlic as modifiers of the risk of cardiovascular disease. J. Nutr. 131:1000S–1005S.

Mbaveng, A., and V. Kuete. 2017. Pages 611–625 in Syzygium Aromaticum, Medicinal Spices and Vegetables from Africa. Elsevier Inc, Amsterdam, Netherlands.

Miah, M., M. Rahman, M. Islam, and M. Monir. 2004. Effects of saponin and L-carnitine on the performance and reproductive fitness of male broiler. Int. J. Poult. Sci. 3:530–533.

Mohammadi, Z., S. Ghazanfari, and M. A. Moradi. 2014. Effect of supplementing clove essential oil to the diet on microflora population, intestinal morphology, blood parameters and performance of broilers. Eur. Poult. Sci. 78:51.

Muaz, K., M. Riaz, S. Akhtar, S. Park, and A. Ismail. 2018. Antibiotic residues in chicken meat: global prevalence, threats, and decontamination strategies: a review. J. Food Protection. 81:619–627.

Mukhtar, M. A. 2011. The effect of dietary clove oil on broiler performance. Aust. J. Basic Appl. Sci. 5:49–51.

Murugesan, G. R., B. Syed, S. Haldar, and C. Pender. 2015. Phytogenic feed additives as an alternative to antibiotic growth promoters in broiler chickens. Fron. Vet. Sci. 2:21.

Mustafa, D. B. M. 2016. Page 89 in Effect of Mixture of Three Herbal Essential Oils on Performance, Carcass Yield and Blood Serum Constituents of Broiler Chicks, MSV Thesis. Sudan University of Science and Technology, Khartoum, Sudan.

Naiel, M. A. E., N. E. Ismael, S. S. Negm, M. S. Ayyat, and A. A. Al-Sagheer. 2020. Rosemary Leaf Powder–Supplemented Diet Enhances Performance, Antioxidant Properties, Immune Status, and Resistance against Bacterial Diseases in Nile Tilapia (*Oreochromis niloticus*). Aquaculture 526:735370.

Oakenfull, D. 1986. Aggregation of saponins and bile acids in aqueous solution. Aust. J Chem 39:1671–1683.

Pino, J. A., R. Marbot, J. Agüero, and V. Fuentes. 2001. Essential oil from buds and leaves of clove (*Syzygium aromaticum* (L.) Merr. et Perry) grown in Cuba. J. Essent. Oil Res. 13:278–279.

Ramadan, M., M. Asker, and M. Tadros. 2013. Lipid profile, antiradical power and antimicrobial properties of *Syzygium aromaticum* oil. Grasas Y Aceites 64:509–520.

Salman, K. A. A.-A., and D. K. Ibrahim. 2012. Test the activity of supplementation clove (*Eugenia caryophyllus*) powder, oil and aqueous extract to diet and drinking water on performance of broiler chickens exposed to heat stress. Int. J. Poult. Sci. 11:635.

Schwean-Lardner, K., and H. Classen. 2010. Lighting for Broilers Aviagen Arbor Acre broiler Management. Handbook.

Shafey, T. M., A. H. Mahmoud, E.-S. Hussein, and G. Suliman. 2014. The performance and characteristics of carcass and breast meat of broiler chickens fed diets containing flaxseed meal. Ital. J. Ani. Sci. 13:3514.

Shan, B., Y. Z. Cai, M. Sun, and H. Corke. 2005. Antioxidant capacity of 26 spice extracts and characterization of their phenolic constituents. J. Agric. Food Chem. 53:7749–7759.

Tariq, H., P. R. Rao, R. S. Raghuvanshi, B. Mondal, and S. Singh. 2015. Effect of Aloe vera and clove powder supplementation on carcass characteristics, composition and serum enzymes of Japanese quails. Vet. World. 8:664.

Velasco, V., and P. Williams. 2011. Improving meat quality through natural antioxidants. Chilean J. Agric. Res. 71:313.

Wankhede, T. 2015. Evaluation of antioxidant and antimicrobial activity of the Indian clove Syzygium aromaticum L. Merr. Perr. Int. Res. J. Sci. Eng. 3:166–172.

Wheeler, T., S. Shackelford, and M. Koohmaraie. 2001. Shear Force Procedures for Meat Tenderness Measurement. Roman L. Hruska US Marc. USDA, Clay Center, NE.

Wilhelm, A. E., M. B. Maganhini, F. J. Hernández-Blazquez, E. I. Ida, and M. Shimokomaki. 2010. Protease activity and the ultrastructure of broiler chicken PSE (pale, soft, exudative) meat. Food Chem 119:1201–1204.